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Selecting Fertilizers

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CONTENTS

INTRODUCTION

The purchaser of commercial fertilizers naturally wants to obtain the greatest value for the money he spends and to get the most benefit from the fertilizer he buys. To be able to do this, he must know what fertilizers contain, how they differ from one another, which differences are of importance in fixing worth or price or both, and what fertilizers he should use, as well as other facts that have a bearing on the problem. The purpose of this circular is to give information that will assist the farmer in selecting fertilizers.

FERTILIZER MATERIALS

Fertilizer materials are generally understood to be commercially obtainable individual materials that contain one or more of the three essential chemical elements—nitrogen, phosphorus, and potassium—in such forms that when the materials are applied to soils, plants may use these elements for their processes of growth. These three elements are normally present in any soil adaptable to crop production, although the quantities of each are apt to vary considerably in different soils. They are, however, in almost all cases the first of the numerous elements in the soil to be removed to such an extent in consequence of continued cropping, leaching, and erosion that the growth of further crops is hindered and finally made unprofitable. The fertilizer industry has been built up around the idea of supplying these elements to the soil in such forms that plants may make use of them, and they are now commonly called the fertilizing elements.

Fertilizer materials do not consist of the fertilizing elements, nitrogen, phosphorus, and potassium, as such. They are more or less pure

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chemical compounds of these elements with other elements or they are complex vegetable or animal materials. The chemical compounds may be obtained from natural sources, as in the case of Chilean sodium nitrate, or manufactured expressly for fertilizer use, as in the case of superphosphate, or made as byproducts in the manufacture of other materials, as in the case of the ammonium sulphate obtained in the manufacture of metallurgical coke or city gas. The vegetable or animal materials may be of natural origin, like guano, or obtained as residues in processing plants and animals, like cottonseed meal and dried blood, or recovered from wastes, as in the case of sewage sludge.

Fertilizer materials are classed as nitrogenous, phosphatic, or potassic according to whether they contain nitrogen, phosphorus, or potassium as their principal or most valuable constituent. Some fertilizer materials may be placed in more than one of these classes. Thus, potassium nitrate is both a nitrogenous and a potassic fertilizer material, and the ammonium phosphates are both nitrogenous and phosphatic.

In the fertilizer trade it is customary to speak of fertilizer materials and mixtures as containing nitrogen, phosphoric acid, and potash instead of nitrogen, phosphorus, and potassium. Until recent years it was also the custom to speak of the ammonia instead of the nitrogen content of fertilizers. The terms ammonia, phosphoric acid, and potash refer to compounds of nitrogen, phosphorus, and potassium, respectively. The early chemists calculated the results of their analyses to these compounds, which served them as convenient means for comparing the relative values of the fertilizers they analyzed even though the nitrogen, phosphorus, and potassium were not actually present in the fertilizers in the form of these compounds. The present custom is merely a relic of the earlier practice.

NITROGENOUS FERTILIZER MATERIALS

Nitrogenous fertilizer materials contain nitrogen in different forms of chemical combination. In some, such as sodium nitrate (nitrate of soda), the nitrogen is combined in the nitrate form. The nitrate form of nitrogen is characterized by ready solubility in water and by being utilized by most crops more quickly than any other form of nitrogen. Plants take up this form of nitrogen directly as such. The nitrate form of nitrogen is, however, the most readily leached from the soil by rains because of its easy solubility and its failure to be fixed in the soil to any considerable extent by the soil constituents.

Other nitrogenous fertilizer materials, such as ammonium sulphate (sulphate of ammonia), contain nitrogen in the form of ammonia or its compounds. Although this ammoniacal form of nitrogen is also soluble in water and the soil solution, it has a tendency to be fixed by certain soil constituents and is therefore much less subject to leaching from the soil than is nitrate nitrogen. Crops may take up ammoniacal nitrogen directly, although much of it is converted in the soil to nitrate nitrogen through the action of soil bacteria before it is utilized by plants.

Still another class of nitrogenous fertilizer materials comprises animal and vegetable substances, such as animal tankage and cottonseed meal, which are commonly known as organic ammoniates. The nitrogen in these materials is in the form of complex organic compounds, such as proteins, and is known as organic nitrogen. For the most part it is insoluble in the soil solution. The insoluble organic nitrogen cannot be used directly by plants but must first be converted by processes of decay into soluble forms. Some of these materials, such as hoof meal and ground leather, decay so slowly in the soil that their nitrogen is of practically no value for promoting plant growth. Fertilizer manufacturers, however, subject such materials to different processes, such as treatment with superheated steam, with or without the addition of sulphuric acid, or mixture with phosphate rock and subsequent treatment with sulphuric acid, to make products most of the nitrogen of which is readily available to crops. The steam-treated products are known as process tankages.

A fourth class of nitrogenous fertilizer materials includes the chemical compounds urea and calcium cyanamide,[1] which contain nitrogen in the amide form. Although they are manufactured synthetically from inorganic substances, they are usually regarded as organic fertilizer materials, since they are carbon compounds and are therefore classed chemically among the organic compounds. Amide nitrogen is readily soluble in the soil solution and quickly changed to the ammoniacal form. The nitrogen in these compounds therefore becomes rapidly available to plants.

Some fertilizer materials may contain nitrogen in more than one form of combination. Cal-Nitro,[2] for instance, contains both ammoniacal and nitrate nitrogen.

The principal nitrogenous fertilizer materials on the market, together with their approximate contents of nitrogen and its forms, are given in table 1. Although fertilizer consumers and manufacturers alike can employ most of these, as well as a number of other less important materials, only the fertilizer manufacturers can afford to make the large investments necessary for the machinery and other equipment required for the utilization of the high-nitrogen liquid products—anhydrous liquid ammonia, etc.—listed at the end of the table, which are sold only in tank-car lots for fertilizer use.

[1] The commercial product is usually sold under the trade name Cyanamid.

[2] A commercial mixture of ammonium nitrate and calcium carbonate. Ammonium nitrate, described on p. 13, contains half its nitrogen as ammonia and half as nitrate nitrogen.

TABLE 1.—*Nitrogen content of principal commercial fertilizer materials and form in which nitrogen occurs*

Material	Ammoniacal nitrogen	Nitrate nitrogen	Organic nitrogen	Amide nitrogen
	Percent	*Percent*	*Percent*	*Percent*
Sulphate of ammonia	19.5-21.2			
Nitrate of soda		15.4-16.5		
Nitrate of potash		12.6-13.5		
Nitrate of soda-potash [1]		13.7-15.5		
Calcium cyanamide [2]				21.0-23.7
Urea				46.0-46.2
Ammonium sulphate-nitrate	19.5	6.5		
Cal-Nitro [3]	7.8-12.5	7.8-12.5		
Ammo-Phos [4]	{ 10.4-11.7 15.8-16.8			
Calurea [5]		6.8		27.2
Calcium nitrate [6]		13.0-15.5		
Animal tankage			5.5-10.0	
Dried blood			6.0-14.0	
Fish scrap, dried			6.5-10.0	
Cottonseed meal			5.3- 7.5	
Castor pomace			4.0- 7.0	
Process tankages			6.5-10.0	
Sewage sludge, activated			4.9- 7.5	
Garbage tankage			3.3	
Cocoa shell meal			2.5	
Ground bone and bonemeals			.7- 5.3	
Tobacco stems			1.3- 1.6	
Uramon [7]				42.0
Anhydrous liquid ammonia	82.2			
Aqua ammonia	20.5-23.5			
Urea-ammonia liquor-A [8]	30.4			15.1
Urea-ammonia liquor-B [8]	25.2			20.1
Crude nitrogen solution [9]	37.0	7.3		
Nitrogen solution II [10]	27.0	10.5		

[1] Often sold as nitrate of potash or Chilean nitrate of potash.
[2] Usually sold under the trade name of Cyanamid.
[3] Commercial product consisting of ammonium nitrate mixed with calcium carbonate. See p. 13 for ammonium nitrate.
[4] Trade name for two commercial products. One is an ammonium phosphate containing approximately 11 percent of nitrogen and 48 percent of phosphoric acid; the other consists of ammonium phosphate and ammonium sulphate and contains approximately 16 percent of nitrogen and 20 percent of phosphoric acid.
[5] Commercial product consisting of calcium nitrate-urea.
[6] Also called nitrate of lime.
[7] Commercial product containing urea and cocoa meal.
[8] Commercial product containing urea and ammonia dissolved in water.
[9] Commercial product containing sodium nitrate and ammonia dissolved in water.
[10] Commercial product containing ammonium nitrate and ammonia dissolved in water.

PHOSPHATIC FERTILIZER MATERIALS

Just as the nitrogenous fertilizer materials contain nitrogen in different forms, phosphatic fertilizer materials contain their phosphoric acid in different forms. In some of them, such as ammonium phosphate and superphosphate, the phosphoric acid is mostly or entirely in water-soluble form, easily soluble in the soil solution and, therefore, readily available to plants.

In others, such as precipitated phosphate, the phosphoric acid is in a form that is practically water-insoluble, though still readily available to plants. This form is commonly known as reverted phosphoric acid. It is also called citrate-soluble phosphoric acid because chemists long ago discovered that, despite its slight solubility in water, it readily dissolved in an ammonium citrate solution and used this test to determine the quantity of reverted phosphoric acid in fertilizers. The sum of the water-soluble phosphoric acid and citrate-soluble phosphoric acid in a fertilizer material is called the available phosphoric acid because both are available for use by plants. In the exceptional case of basic slag, a material that has value both as a phosphatic fertilizer and as a liming agent, the available phosphoric acid is that which is soluble in a citric acid solution.

Still other phosphatic fertilizer materials have much or most of their phosphoric acid in forms that are less soluble in the soil solution than citrate-soluble phosphoric acid. Since they are contained in the residue that remains when the chemist dissolves out the citrate-soluble phosphoric acid from fertilizers, these forms are collectively known as citrate-insoluble phosphoric acid or simply as insoluble phosphoric acid. Their solubility is often so slight that they cannot be readily utilized by plants. Under some conditions insoluble phosphoric acid is rendered sufficiently soluble in the soil, especially acid soil, to be available to crops. Also, in soils that contain considerable organic matter, certain products of the decay of this organic matter increase the solubility of the insoluble phosphoric acid so that it may be more readily taken up by crops.

Of the materials that contain considerable quantities of insoluble phosphoric acid, those, such as bonemeal and fish scrap, that contain organic matter and are therefore also valuable as nitrogenous materials are most used without previous chemical treatment for fertilizer purposes. However, ground or other finely divided forms of phosphate rock are also employed to some extent. Only the total quantity of phosphoric acid in such materials is customarily determined.

The principal phosphatic fertilizer materials together with their approximate phosphoric acid contents are listed in table 2.

Table 2.—*Phosphoric acid content of fertilizer materials*

Material	Available phosphoric acid	Total phosphoric acid	Material	Available phosphoric acid	Total phosphoric acid
	Percent	*Percent*		*Percent*	*Percent*
Superphosphate	13.5–22.0		Bonemeal and ground bone		17.0–30.0
Double (treble, triple) superphosphate	40.0–50.0		Animal tankage		5.0–18.0
Ammo-Phos [1]	20.0–22.8 48.0–52.6		Garbage tankage		4.5
Precipitated phosphate	37.0–42.0		Fish scrap, dried		5.0–8.0
Basic slag	[2] 5.0–20.0		Ground phosphate rock and other phosphatic mineral products		12.0–35.0
Sewage sludge	2.0–3.6				

[1] See footnote 4, table 1.

[2] The basic slag produced in this country is sold on the basis of a content of 8 percent of total phosphoric acid.

POTASSIC FERTILIZER MATERIALS

Unlike the nitrogenous and phosphatic fertilizer materials, which contain their nitrogen and phosphoric acid in forms that differ with respect to their availability to crops, all commercial potassic fertilizer materials contain potash in water-soluble forms that are alike regarding availability. The principal potassic fertilizer materials and the approximate ranges of their potash contents are shown below.

Material:	*Percent of potash*
Potassium chloride (muriate of potash)	47 –61.5
Potassium sulphate (sulphate of potash)	47 –52
Potassium nitrate (nitrate of potash)	42.9–45.2
Nitrate of soda-potash [1]	13.7–16.4
Manure salts	25 –32
Sulphate of potash-magnesia	26 –29
Kainite	20 –22
Cotton hull ashes	20.5–34.8
Hardwood ashes	1.5–8.0
Tobacco stems	4.4–5.4

[1] Often sold as nitrate of potash or Chilean nitrate of potash.

FERTILIZER MIXTURES

In European countries farmers customarily apply individual fertilizer materials to the soil, but this procedure is not extensively used in the United States. The usual practice here is to use mixtures of different fertilizer materials the relative quantities of which have been so chosen as to give a product that contains nitrogen, phosphoric acid, and potash in desired proportions. These mixtures are for the most part made and sold by fertilizer manufacturers, though home mixing is done to a limited extent. Only about 30 percent of the fertilizers sold to farmers in this country are separate fertilizer materials. Commercial fertilizers are commonly sold under trade names arbitrarily chosen by the manufacturers and sometimes designed to catch the fancy of the purchaser. These names are called brand names.

All the States except Nevada have enacted laws which require that each container of a fertilizer bear, or have attached, a statement of the minimum percentages of nitrogen, available phosphoric acid, and water-soluble [3] potash that are guaranteed to be present in the fertilizer. Additional information, such as a statement of the forms or sources of the nitrogen and the percentages of the nitrogen derived from each source, or the percentage of chlorine present, is required in many States.

The grade of a fertilizer is expressed by the figures that show the percentages of nitrogen, available phosphoric acid, and potash contained in it, for example, 4–8–4. The first figure usually indicates the percentage of nitrogen, the middle figure the percentage of available phosphoric acid, and the last figure the percentage of water-soluble potash. In South Dakota the available phosphoric acid and the water-soluble potash are expressed as the elements phosphorus and potassium, respectively. Mixtures that contain nitrogen, phosphoric acid, and potash, like the above-mentioned 4–8–4, are called complete fertilizers. Approximately 96 percent of the mixtures sold are complete fertilizers. Incomplete mixtures like 0–10–4 and 0–12–5, which contain phosphoric acid and potash but no nitrogen, comprise practically all the remainder.

A survey of the fertilizers sold in the United States disclosed that 1,291 different grades were sold in 1934. Of this number, approximately one-third (425) were sold in Florida alone, though this State accounted for only 5.7 percent (183,295 tons) of the total of 3,068,889 tons of fertilizer reported in the survey. Even in this State, about one-half the tonnage was represented by a dozen grades, and one-half the grades represented less than 25 tons of fertilizer each. Although soils vary in their relative supplies of available nitrogen, phosphoric acid, and potash and crops vary in their relative requirements of each, agronomists and fertilizer manufacturers agree that the number of grades of fertilizer used is greatly in excess of the need. In many sections of the country definite progress toward the elimination of unnecessary grades has been made as the result of conferences of

[3] It has been found that frequently a small quantity of the water-soluble potash of potassic fertilizer materials fails to dissolve in water when these materials are contained in fertilizer mixtures, though it is still available to plants. Fertilizer-control chemists have recently adopted a method for determining available potash in fertilizer mixtures, which consists in finding the quantity of potash soluble in an ammonium oxalate solution. As a result, the fertilizer laws of the different States will probably be changed to permit a statement of the guaranteed content of available potash instead of water-soluble potash.

fertilizer-control officials and State agricultural workers with the manufacturers. A reduction in the number of grades should lower the costs of manufacturing and selling fertilizers as well as make the problem of the selection of proper fertilizers easier for the consumer.

SELECTION OF FERTILIZER ACCORDING TO SOIL AND CROP

The relative amounts of nitrogen, phosphoric acid, and potash that should be applied to a particular soil to give the best results with a particular crop can best be determined by experiment. One of the tasks of the State agricultural experiment stations is to conduct such experiments for the benefit of the farmers. The Bureau of Plant Industry of the United States Department of Agriculture,[4] in cooperation with many of the State agricultural experiment stations, has also conducted extensive investigations on this subject.

Since the crops and soils of the different sections of the country vary, the farmer who wishes to know what ratios of nitrogen, phosphoric acid, and potash in fertilizers are best suited for his require-

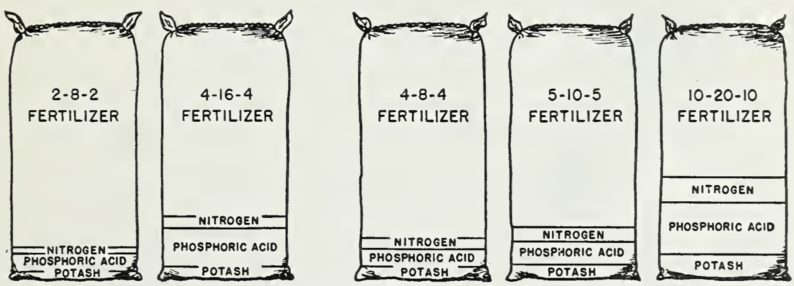

FIGURE 1.—Relative quantities of plant nutrients in commercial fertilizers.

ments should make inquiry of the director of the agricultural experiment station of his own State or his county agent, who is a representative both of the United States Department of Agriculture and of his State. The addresses of the respective directors are listed in the Appendix.

SELECTION OF FERTILIZER ACCORDING TO CONCENTRATION

As a rule, farmers are inclined to buy fertilizers on a ton basis, losing sight of the fact that the value of a fertilizer is determined by the quantities of plant nutrients—nitrogen, phosphoric acid, and potash—that it contains. Examination of the numerous grades of fertilizers on the market reveals that certain grades contain the same relative amounts of the plant nutrients, though the total amounts are different (fig. 1). Examples of these are (1) 2–8–2 and 4–16–4 and (2) 4–8–4, 5–10–5, and 10–20–10. Although the ratios of the plant nutrients in both the fertilizers of (1) are 1 to 4 to 1, the 2–8–2 grade contains 12 percent of plant food and the 4–16–4 grade contains 24 percent. A ton of the 2–8–2 grade, therefore, contains 12 percent of 2,000 pounds,

[4] Typical examples of publications of the U. S. Department of Agriculture that give the results and conclusions of such work are: Leaflet 71, Fertilizers for Pecan Soils; Circular 319, Fertilizer Studies with Sugar Beets in the Arkansas Valley Area, Colorado, 1921–28; Technical Bulletin 12, Fertilizer Tests with Flue-Cured Tobacco; Technical Bulletin 335, Fertilizers for Sweetpotatoes Based on Investigations in North Carolina; Miscellaneous Publication 126, Fertilizers for Cotton Soils.

or 240 pounds, of plant food, whereas a ton of the 4–16–4 grade contains 480 pounds of plant food. A ton of the 4–16–4 grade, therefore, contains twice as much plant food as a ton of the 2–8–2 grade.

Expressed in another way, the buyer of the 2–8–2 grade must purchase 2 tons to get the same quantity of plant food that the buyer of the 4-16-4 grade gets when he purchases 1 ton (fig. 2). Similarly, the

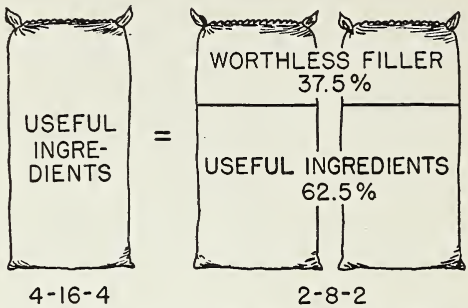

FIGURE 2.—One ton of a 4–16–4 fertilizer contains as much plant food as 2 tons of a 2–8–2 fertilizer.

buyer of a ton of the 10–20–10 grade gets 800 pounds, or twice as much of the valuable plant nutrients as the buyer of a ton of the 5–10–5 grade and two and a half times as much as the purchaser of a ton of the 4–8–4 grade, though the ratios of the plant nutrients are in each case 1 to 2 to 1. In such cases, the purchaser of the higher grade or more concentrated mixture pays more per ton for his fertilizer, but the cost of the plant food he gets is less. To illustrate this, let us compare the average retail prices in several States on August 15, 1934, for the same quantities of plant nutrients in fertilizers of the grades mentioned above (table 3).

TABLE 3.—*Average retail prices in several States on Aug. 15, 1934, for the same quantities of plant nutrients in fertilizers of different grades, ratios, and quantities*

	North Carolina	Indiana
Ratio 1 to 4 to 1:		
2 tons 2–8–2	$46.30	$49.72
1 ton 4–16–4	34.35	39.82
Saving	11.95	9.90

	New York	New Jersey	Georgia
Ratio 1 to 2 to 1:			
2½ tons 4–8–4	$72.13	$67.88	$72.63
2 tons 5–10–5	67.50	62.50	66.20
Saving	4.63	5.38	6.43
2 tons 5–10–5	67.50	62.50	66.20
1 ton 10–20–10	57.35	54.85	56.44
Further saving	10.15	7.65	9.76

The farmers in North Carolina and Indiana who bought 2 tons of 2–8–2 fertilizer not only paid, on the average, $11.95 and $9.90, respectively, more for the same quantity of fertilizing elements than they would have paid for 1 ton of 4–16–4 fertilizer but they also had the trouble and expense of handling an extra ton of material. The farmers in New York, New Jersey, and Georgia who bought 1 ton of 10–20–10, instead of the 2 tons of 5–10–5 that would have been necessary to furnish the same quantity of fertilizing elements, saved $10.15, $7.65, and $9.76, respectively. Those who bought 1 ton of the 10–20–10, instead of 2½ tons of the 4–8–4, saved $14.78, $13.03, and $16.19, respectively.

A fertilizer such as the 2–8–2 grade is a low-grade mixture. To make such low-grade fertilizers, the manufacturers are compelled to use worthless materials, known as fillers, to bring the weight of the mixture of fertilizer materials up to a ton. It costs just as much to handle, bag, and haul this filler, pound for pound, as it does to handle, bag, and haul the fertilizer materials contained in the mixture. The purchaser must pay this added expense. Although, like all commodities, fertilizers are subject to price variations, and the prices given above no longer hold, savings of approximately the same sums may still be made by farmers who purchase the higher grade fertilizers in preference to the lower grades.

The fertilizers in figure 2 were prepared according to the formulas given in table 4.

TABLE 4.—*Comparison of fertilizers shown in figure 2*

Material	Quantity per ton in—	
	4–16–4 fertilizer	2–8–2 fertilizer
	Pounds	*Pounds*
Superphosphate, 20-percent phosphoric acid	700	800
Double superphosphate, 45-percent phosphoric acid	400	
Potassium chloride, 50-percent potash	160	80
Ammonium sulphate, 20-percent nitrogen	200	100
Sodium nitrate, 16-percent nitrogen	164	82
Organic ammoniate, 7-percent nitrogen	200	100
Dolomite, sufficient to make neutral	176	88
Filler (sand)		750
Total	2,000	2,000

Not only when buying mixed fertilizers but also when buying individual fertilizer materials farmers should give consideration to the quantity of plant nutrients in a ton of material as well as to the price per ton of the material. When buying nitrogenous, phosphatic, or potassic materials, the division of the guaranteed percentage of nitrogen, phosphoric acid, or potash into the price charged per ton of the material will show how much is paid for each percent, or 20 pounds, of plant food obtained. Thus, when 16-, 18-, and 20-percent superphosphates are priced at $17.50, $18.75, and $20.60 a ton, the cost is $1.09, $1.04, and $1.03 for each 20 pounds of available phosphoric acid obtained in the respective materials.

SELECTION OF FERTILIZER ACCORDING TO INFLUENCE ON SOIL REACTION

Soils may naturally be acid, alkaline, or neutral, that is, intermediate, in reaction. Although certain plants, such as alfalfa and asparagus, grow best on neutral or slightly alkaline soils, and others, such as blueberries and cranberries, do best on decidedly acid soils, most crops thrive best on slightly acid soils. Each crop, in fact, grows well within a particular range of soil reactions, and its growth is hindered more and more the further the soil reaction departs from this range until a point is reached where growth does not take place. The influence of fertilizers upon the reactions of the soils to which they are added is, therefore, of considerable importance.

Of the fertilizer materials used extensively in the preparation of fertilizer mixtures, only the nitrogenous materials have a definite influence on soil reaction. The nitrates—sodium nitrate, potassium nitrate, and calcium nitrate—and calcium cyanamide cause soils to become less acid or more alkaline in reaction, whereas the ammonium salts and urea cause them to become more acid or less alkaline in reaction. The ammonium salts are particularly acid-forming. The different organic ammoniates vary; most of them are slightly acid-forming, but some decrease soil acidity. The influence of mixed fertilizers upon the reaction of soils is determined primarily by the relative proportions of the different forms of nitrogen used in their preparation. Table 5 shows that whereas organic ammoniates formerly supplied most of the nitrogen in fertilizer mixtures, the proportion of nitrogen furnished by ammoniacal salts and ammonia has increased to such an extent as to constitute more than half the nitrogen in present-day mixtures.

TABLE 5.—*Forms of nitrogen contained in mixed fertilizers in specified years*

Year	Ammoniacal	Nitrate	Organic	Amide	Year	Ammoniacal	Nitrate	Organic	Amide
	Percent	*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*
1880	7.83	3.91	88.26	----------	1915	24.54	23.15	49.07	3.24
1885	17.50	5.00	77.50	----------	1920	24.55	29.55	37.26	8.64
1890	14.41	7.63	77.96	----------	1925	38.13	21.94	30.94	8.99
1895	7.50	17.92	74.58	----------	1930	54.71	12.77	24.62	7.90
1900	5.74	23.44	70.82	----------	1931	57.44	11.61	23.51	7.44
1905	10.19	25.00	64.81	----------	1932	56.33	14.02	18.33	11.32
1910	26.32	18.42	55.26	----------					

Consequently, unless the manufacturer has used a liming material, such as limestone or dolomite, in its preparation, the average fertilizer mixture now purchasable by the farmer will be decidedly acid-forming. Although in certain cases the use of an acid-forming fertilizer is desirable, as when a soil has been overlimed or when, in raising potatoes, the crop is affected by scab, the continued use of such acid-forming fertilizers will increase the acidity of the soils to which they are applied until a point is reached where the growth of crops is hindered. In fact, many soils, particularly in the Southeastern States, have already reached acidities that are harmful to plant growth. The farmer who does not follow the practice of liming his soil at regular intervals should, therefore, ascertain whether the fertilizer mixtures he purchases are acid-forming or nonacid-forming. In a few States, fertilizer control officials now require a statement on the tag of each bag showing whether the fertilizer is acid-forming or not.

SELECTION OF FERTILIZER ON THE BASIS OF THE PRESENCE OR ABSENCE OF ORGANIC NITROGEN

In the early days of the fertilizer industry the organic ammoniates were generally the cheapest sources of nitrogen for use in fertilizers. Consequently, they supplied most of the nitrogen contained in commercial fertilizer mixtures. Now, however, they are the most expensive sources of nitrogen. A number of factors are responsible for this. With few exceptions, organic ammoniates have been used more and more as feed for stock, for which they have a greater value than as fertilizer. The price of the nitrogen in Chilean sodium nitrate, which formerly was maintained by foreign monopolistic control near that of the nitrogen in the organic ammoniates, has been decreased to maintain competition with other newer and cheaper sources of nitrogen. The invention of commercially successful methods for fixing the nitrogen of the air has resulted in an abundant supply of compounds that contain nitrogen in ammoniacal, nitrate, and amide forms and at a cost for nitrogen considerably below that which formerly prevailed. The use of organic ammoniates at a cost of the nitrogen therein of two, three, and even more times that of the nitrogen in other fertilizer materials necessarily increases the cost of the mixtures that contain them. Nevertheless, many farmers demand that the fertilizers they buy contain organic nitrogen. The question arises as to whether the increased cost is justified. The results of recent experimental field work in different parts of the country indicate that the different forms of nitrogen in mixed fertilizers produce similar crop yields, provided that such fertilizers, when acid-forming, are made nonacid-forming by the inclusion of suitable neutralizing materials.

FERTILIZER CONTROL

As previously stated, all States except Nevada have laws that govern the sale of fertilizers within their boundaries. These laws have been enacted for the protection of buyers and honest manufacturers. The enforcement of these laws is vested in fertilizer-control officials, who are empowered to take samples of the fertilizers that have been sold or are offered for sale and have them analyzed to ascertain whether the guarantees made concerning them are fulfilled. The results of these analyses are usually made available in publications, which also frequently contain other valuable information, such as commercial valuations of the fertilizers examined and tables of the wholesale prices of the plant nutrients in various forms. These publications are distributed free to applicants within the individual States. A list of the fertilizer-control officials is given in the Appendix.

ELEMENTS OTHER THAN NITROGEN, PHOSPHORUS, AND POTASSIUM

Soils contain many elements other than nitrogen, phosphorus, and potassium. Certain of these are just as essential for plant growth as the three fertilizing elements. They are, however, generally present in the soil in sufficient quantities to meet crop requirements.

and the necessity for adding them to soils is far less frequent than is the case with the three elements thus far discussed. Three of these elements—calcium, sulphur, and magnesium—are used to a larger extent by crops than the others. It happens, however, that calcium is a constituent of superphosphate, the most extensively used of all fertilizer materials, and that sulphur is also a constituent of superphosphate, as well as of ammonium sulphate, the most extensively used of the nitrogenous fertilizer materials, and of potassium sulphate and certain other potash materials. The user of ordinary fertilizer mixtures, therefore, furnishes his soil with an ample supply of calcium and sulphur for all crop requirements. Cases of magnesium deficiency, however, have been recognized in recent years in crops grown on a number of light, sandy soils, especially those of the States that border on the Atlantic Ocean and the Gulf of Mexico. The greater use of more concentrated potash salts in fertilizer mixtures, instead of the low-grade potash salts, such as kainit, which were formerly extensively employed, and also the decreased use in fertilizers of cottonseed meal, which contains about 0.5 percent of magnesium, undoubtedly decreased the quantity of magnesium supplied to soils by fertilizers. On the other hand, the use of dolomite and dolomitic limestone to produce nonacid-forming fertilizers, the addition of magnesium sulphate to fertilizers, and the use of sulphate of potash-magnesia as a source of both potassium and magnesium are factors that tend again to increase the quantities of magnesium supplied to the soil.

Occasional deficiencies of soils in other elements that are required by plants in considerably smaller amounts than calcium, sulphur, and magnesium have been found. A common characteristic of these elements—manganese, copper, zinc, and boron—is that although small quantities of them are essential for plant growth, larger quantities actually cause injury. Caution is necessary, therefore, in the application of these elements to the soil. The farmer, consequently, should not undertake to supply them to his soil until he has consulted his State agricultural experiment station as to the need for them and the quantity to be applied. A number of fertilizer manufacturers at present add small quantities of these elements to the fertilizer mixtures they prepare, especially mixtures intended for use in localities in which the soils are deficient in them. They also are present in small amounts as normal constituents of many of the ordinary fertilizer materials. Manganese deficiency has usually been found in calcareous or limestone soils or in soils that have been limed until they are neutral or alkaline in reaction. The manganese in such soils is practically all in an insoluble form and therefore not available to plants. Manganese deficiency is prevalent in the calcareous soils of Dade County, Fla., where the use of manganese sulphate, a soluble form of manganese, has become common practice.

Copper deficiency has been observed in some peat soils in Florida, New York, and Michigan. Some Florida soils are also deficient in zinc. Certain soils in Delaware County and on Long Island, N. Y., and in New Jersey are deficient in boron.

GRANULATED FERTILIZER MIXTURES

Commercial fertilizer mixtures are usually made by placing in a mixing machine the quantities of the different materials necessary to make up a given weight of the desired mixture and then subjecting them to a mechanical mixing operation. The different materials usually differ in the relative sizes of their individual particles as well as in their relative heaviness (specific gravity). As a result, although the mixture may be very uniform when it leaves the mixing machine, the different materials tend to separate from each other, or segregate, during the different handling processes to which the mixture is subjected between the mixing machine and final lodgment in the soil. In consequence of this segregation, the mixture ceases to be uniform throughout, and when it is applied in the field the same relative amounts of the different fertilizing elements are not placed within reach of the roots of the different plants. A given plant, therefore, may have at its disposal more of one of the fertilizing elements than it requires, while at the same time it may not be provided with enough of another element for its full development. To overcome segregation in mixed fertilizers, methods of granulation have recently been devised which will insure that each granule of a mixed fertilizer contain substantially the same relative proportions of the different materials constituting the mixture. The granulation of fertilizer mixtures not only prevents segregation but also reduces the tendency of mixtures to cake or become sticky. It also increases the ease with which the mixture can be applied to the soil by fertilizer distributers. Granulated mixtures are now on the market.

NEW FORM OF AMMONIUM NITRATE

Although ammonium nitrate has been used in fertilizers for many years, the use of the nearly pure material has been possible only since 1943. Solid ammonium nitrate formerly was sold as a mixture under various names, including Cal-Nitro, and in solution of ammonia and water as Nitrogen Solution II (table 1). Pure ammonium nitrate as a white crystalline solid is made from nitric acid and ammonia and contains half the nitrogen as nitrate and half as ammonia. It became available from Army Ordnance plants early in 1943, but on account of its absorption of water from the air and its property of caking it could not at first be employed. A treatment was developed to overcome these difficulties, and ammonium nitrate coated with inert powder to prevent caking is now marketed in granular form, and shipped in bags laminated with asphalt to protect it from moisture. In this form it contains about 32.5 percent nitrogen, is readily soluble in water, and has proved to be of high fertilizer value. It will probably constitute one of the main sources of nitrogen in the postwar period.

APPLICATION OF FERTILIZERS

A farmer may buy a fertilizer containing the fertilizing elements in proportions best suited for his soil and crop and in a concentration that gives the largest quantity of the fertilizing elements for his money and yet fail to get the best crop yields that are obtainable from its use because of failure to apply it properly. Numerous recent experiments have shown that not only the kind and amount of fertilizer applied but also the way in which the fertilizer is placed with respect to the seed or the plant has an important bearing on the size of the crop obtained (fig. 3). Thus, in the case of row crops, such as cotton,

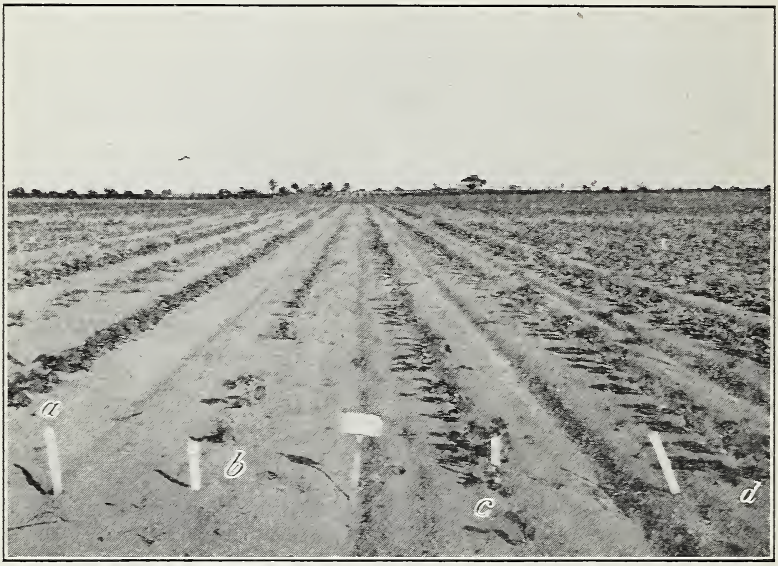

FIGURE 3.—Cotton planted on Norfolk sand to Ruston loamy sand, Columbia, S. C., April 20; photographed June 25; 4–8–4 fertilizer was applied at the rate of 800 pounds per acre in the following placements with respect to the seed: *a*, In bands 2½ inches to each side, 3 inches below seed; *b*, in a 1¾-inch band, 3 inches below seed; *c*, in bands 2½ inches to each side, 2 inches below seed on land bedded 8 days before planting; *d*, in bands 2½ inches to each side, 2 inches below seed.

potatoes, and tobacco, the application of the fertilizer in bands at the sides of the row or hill has in general given better results than any other method of application. Increased knowledge concerning proper methods for the application of fertilizers has also brought about improvements in fertilizer-distributing machinery.

The reader who desires to know the details of these new developments and how they may be applied to his own particular circumstances should consult the Bureau of Plant Industry, Soils, and Agricultural Engineering, Plant Industry Station, Beltsville, Md., or his own State agricultural experiment station.

APPENDIX

ADDRESSES OF THE DIRECTORS OF THE STATE AGRICULTURAL EXPERIMENT STATIONS

Alabama: Auburn.
Alaska: College.
Arizona: Tucson.
Arkansas: Fayetteville.
California: Berkeley.
Colorado: Fort Collins.
Connecticut: New Haven.
Delaware: Newark.
Florida: Gainesville.
Georgia: Experiment.
Hawaii: Honolulu.
Idaho: Moscow.
Illinois: Urbana.
Indiana: La Fayette.
Iowa: Ames.
Kansas: Manhattan.
Kentucky: Lexington.
Louisiana: Baton Rouge.
Maine: Orono.
Maryland: College Park.
Massachusetts: Amherst.
Michigan: East Lansing.
Minnesota: University Farm, St. Paul.
Mississippi: State College.
Missouri: Columbia.
Montana: Bozeman.
Nebraska: Lincoln.
Nevada: Reno.
New Hampshire: Durham.
New Jersey: New Brunswick.
New Mexico: State College.
New York: Geneva; Ithaca.
North Carolina: State College Station.
North Dakota: Fargo.
Ohio: Wooster.
Oklahoma: Stillwater.
Oregon: Corvallis.
Pennsylvania: State College.
Puerto Rico: Mayaguez; Rio Piedras.
Rhode Island: Kingston.
South Carolina: Clemson College.
South Dakota: Brookings.
Tennessee: Knoxville.
Texas: College Station.
Utah: Logan.
Vermont: Burlington.
Virgin Islands: Christiansted.
Virginia: Blacksburg.
Washington: Pullman.
West Virginia: Morgantown.
Wisconsin: Madison.
Wyoming: Laramie.

STATE FERTILIZER-CONTROL OFFICIALS

Alabama: Commissioner of agriculture and industries, Montgomery.
Arizona: State chemist, Tucson.
Arkansas: Commissioner of revenue, Little Rock.
California: Director, departmentment of agriculture, Sacramento.
Colorado: Director of agriculture, experiment station, Denver.
Connecticut: Director, Connecticut (State) Agricultural Experiment Station, New Haven.
Delaware: Secretary, State board of agriculture, Dover.
Florida: Commissioner of agriculture, Tallahassee.
Georgia: Commissioner of agriculture, Atlanta.
Idaho: Commissioner of agriculture, Moscow.
Illinois: Superintendent, division of foods and dairies, Chicago.
Indiana: State chemist, agricultural experiment station, La Fayette.
Iowa: Secretary, department of agriculture, Des Moines.
Kansas: Secretary, State board of agriculture, Topeka.
Kentucky: Director, agricultural experiment station, Lexington.
Louisiana: Commissioner, department of agriculture and immigration, Baton Rouge.
Maine: Commissioner of agriculture, Augusta.
Maryland: President and executive officer, State board of agriculture, College Park.
Massachusetts: Official chemist, experiment station, Amherst.
Michigan: Commissioner of agriculture, Lansing.
Minnesota: Commissioner, department of agriculture, dairy, and food, St. Paul.
Mississippi: Commissioner, department of agriculture and commerce, Jackson.
Missouri: Director, agricultural experiment station, Columbia.
Montana: Commissioner of agriculture, labor, and industry, Helena.
Nebraska: Director, department of agriculture and inspection, Lincoln.
New Hampshire: Commissioner of agriculture, Concord.
New Jersey: State chemist, New Brunswick.
New Mexico: Deputy in charge, New Mexico feed and fertilizer control office, State College.

New York: Commissioner of agriculture and markets, Albany.
North Carolina: Commissioner of agriculture, Raleigh.
North Dakota: Commissioner, State food commission, Bismarck.
Ohio: Director of agriculture, Columbus.
Oklahoma: Chief inspector, State board of agriculture, Oklahoma City.
Oregon: Director, department of agriculture, Salem.
Pennsylvania: Secretary of agriculture, Harrisburg.
Puerto Rico: Commissioner of agriculture and commerce, Rio Piedras.
Rhode Island: Director, department of agriculture and conservation, Providence.
South Carolina: Secretary, board of fertilizer control, Clemson College.
South Dakota: Director of inspection, Pierre.
Tennessee: Commissioner of agriculture, Nashville.
Texas: State chemist and chief, division of chemistry, agricultural experiment station, College Station.
Utah: Commissioner, State board of agriculture, Salt Lake City.
Vermont: Director, agricultural experiment station, Burlington.
Virginia: Commissioner of agriculture and immigration, Richmond.
Washington: Director of agriculture, Olympia.
West Virginia: Commissioner of agriculture, Charleston.
Wisconsin: Director, department of agriculture, Madison.
Wyoming: State chemist, Cheyenne.

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